

NEWS & VIEWS

Star clusters: Anything but simple

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The heated debate on the importance of stellar rotation and age spreads in massive star clusters has just become hotter by throwing stellar variability into the mix.

A quiet revolution has been sweeping the field of star-cluster astrophysics. A decade ago, we were reasonably convinced that we understood the formation and evolution of the massive, well-populated star clusters that can be used as a statistical tool for studies of stellar evolution. Groups of stars characterized by a common age and chemical composition were considered ‘simple stellar populations’, given that all of their stars had presumably formed from the same progenitor molecular gas cloud at approximately the same time. Admittedly, the oldest galactic building blocks, the globular clusters, were known to exhibit evidence of multiple stellar generations¹, but clusters younger than a few billion years appeared to obey our simple models. Fast forward a decade, and we now know that the majority of 1–3 billion-year-old star clusters in the nearest galaxies, the Magellanic Clouds, are anything but simple. Indeed, writing in *The Astrophysical Journal Letters*, Ricardo Salinas and co-workers show that a significant population of pulsating stars can have a measurable effect on our interpretation of stellar evolution within such clusters².

Deviations from the simple stellar population model show up most readily in a cluster’s colour–magnitude diagram. This type of plot is the observational counterpart to the theoretical Hertzsprung–Russell diagram, which relates the temperatures (or colours) of the cluster’s stars to their luminosities. Instead of being randomly distributed, the stars tend to lie on bands. Most stars, including the Sun, belong to the ‘main sequence’, when they are fusing hydrogen into helium in their cores. By mapping a stellar population in this manner, it is possible to estimate the age of the stars in a given cluster.

Most of the ‘intermediate-age’ clusters in the Magellanic Clouds exhibit extended regions in colour–magnitude space^{3,4} at the ‘main-sequence turn-off’—the evolutionary phase where stars have exhausted their core hydrogen—but still on the ‘main sequence’, before commencing hydrogen fusion in a thin shell surrounding their cores. Single-aged, single-metallicity stellar populations would, instead, exhibit narrow ridgelines and sharp turn-offs. Initial explanations for the extended main-sequence turn-off areas suggested that massive clusters might have continued forming stars for some time following a cluster’s initial burst of star formation⁵. This would also generate a range of metal abundances over time as new generations of stars formed from the chemically enhanced debris of their progenitors. This idea has lost traction in recent years with the realization that star clusters may be composed of coeval stellar populations after all, but whose stars might be characterized by a range of rotation rates⁴.

In the classical ‘instability strip’ in the Hertzsprung–Russell diagram, stars become unstable and exhibit pulsations because of cycli-

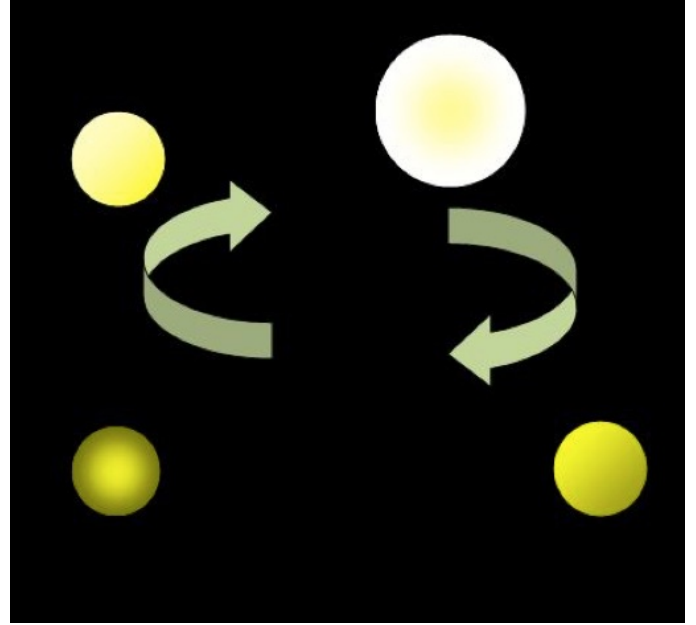


Figure 1 | Heart of brightness. Variable stars such as the δ Scuti variables change their luminosity and temperature in a periodic fashion, thus appearing to pulsate. In the dimmest phase, the outer shell is rich in He^{2+} and is opaque, so radiation from within gets trapped. As it warms, the star expands and cools. The He^{2+} then converts to He^+ , which is more transparent, allowing the heat to escape. As the star continues to cool, the expansion stops, and eventually reverses under the star’s own gravity. (Figure adapted from Antonine Education)

cal abundance changes of singly and doubly ionized helium in their atmospheres⁶ (Fig. 1). It crosses the main sequence for A- and F-type stars, that is, for stars with masses ranging from approximately 1.5 to 2.5 solar masses. Conventional stellar evolution theory implies that such stars occupy the main-sequence turn-offs in coeval star clusters with ages of about 1–3 billion years. The majority of main-sequence turn-off stars are stable, even those located inside the instability strip. Yet, certain stellar types exhibit photometric variability, including the rapidly oscillating peculiar A-type (‘roAp’) stars, SX Phoenicis and δ Scuti variables. The δ Scuti variables show periodic luminosity changes ranging from 30 minutes to 8 hours, which are driven by both radial and non-radial (wave-like) pulsations on the stellar surface.

Salinas *et al.*² point out that the effects of the luminosity and colour changes of δ Scuti stars in the main-sequence turn-off area have been completely ignored. The authors analyse theoretical colour–magnitude diagrams, varying both the fraction of the main-sequence stars residing in the instability strip which are actually pulsating variables—a ratio known as the ‘incidence’—and their maximum photometric amplitudes. Their first important conclusion states that the density of cluster stars near the observational ridgeline (or, alternatively, the theoretical

isochrone) decreases as the incidence increases from 10% to 50%, with the distribution becoming as much as 50% wider for the highest incidence.

Second, and perhaps most interesting, their analysis implies that the extent of the main-sequence turn-off region owing to the presence of δ Scuti stars is maximal for cluster ages around 2 billion years. Clusters younger than 1 billion years or those older than 2.5 billion years are not affected because of the complex interplay between the location of δ Scuti stars on the main sequence and its age-dependent overlap with the instability strip. This fresh insight is eerily similar to the results from a recent independent analysis which considered the apparent internal cluster age spread implied by the extent of the main-sequence turn-off as a function of cluster age, reaching a maximum at an age of 1.5–1.7 billion years⁷.

The results of Salinas and co-workers are intriguing and offer significant food for thought. They naturally explain the observed absence both of broadened subgiant branches in the colour–magnitude diagrams⁸ and of extended red clumps⁹. Yet, the actual incidence of δ Scuti variables in single-aged star clusters is unknown, so that current estimates are necessarily based on the properties of their counterparts among the Milky Way’s field stellar population—perhaps not the best comparison sample. Observational data to confirm or reject these novel

insights are, unfortunately, challenging to obtain. As there are no suitable young or intermediate-age clusters available in our Milky Way, we would need to secure time-series observations at high spatial resolution of 1–3 billion-year-old star clusters in the Magellanic Clouds. This approach would require *Hubble Space Telescope* capabilities; even with their adaptive optics capability turned on, the European Southern Observatory’s Very Large Telescope cannot attain the resolution needed, given the Magellanic Clouds’ location deep in the southern hemisphere and the correspondingly large air column affecting such observations. Therefore, the viability of the Salinas *et al.* proposal remains to be tested, but at least the field can now move forward again.

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